

# ***ROCK SLOPES STABILIZATION MEASURES – REINFORCEMENT METHODS***

## ***Lesson 8 – Topic B***

# ***LESSON 8B – ROCK REINFORCEMENT METHODS***

## ***Learning Outcomes -***

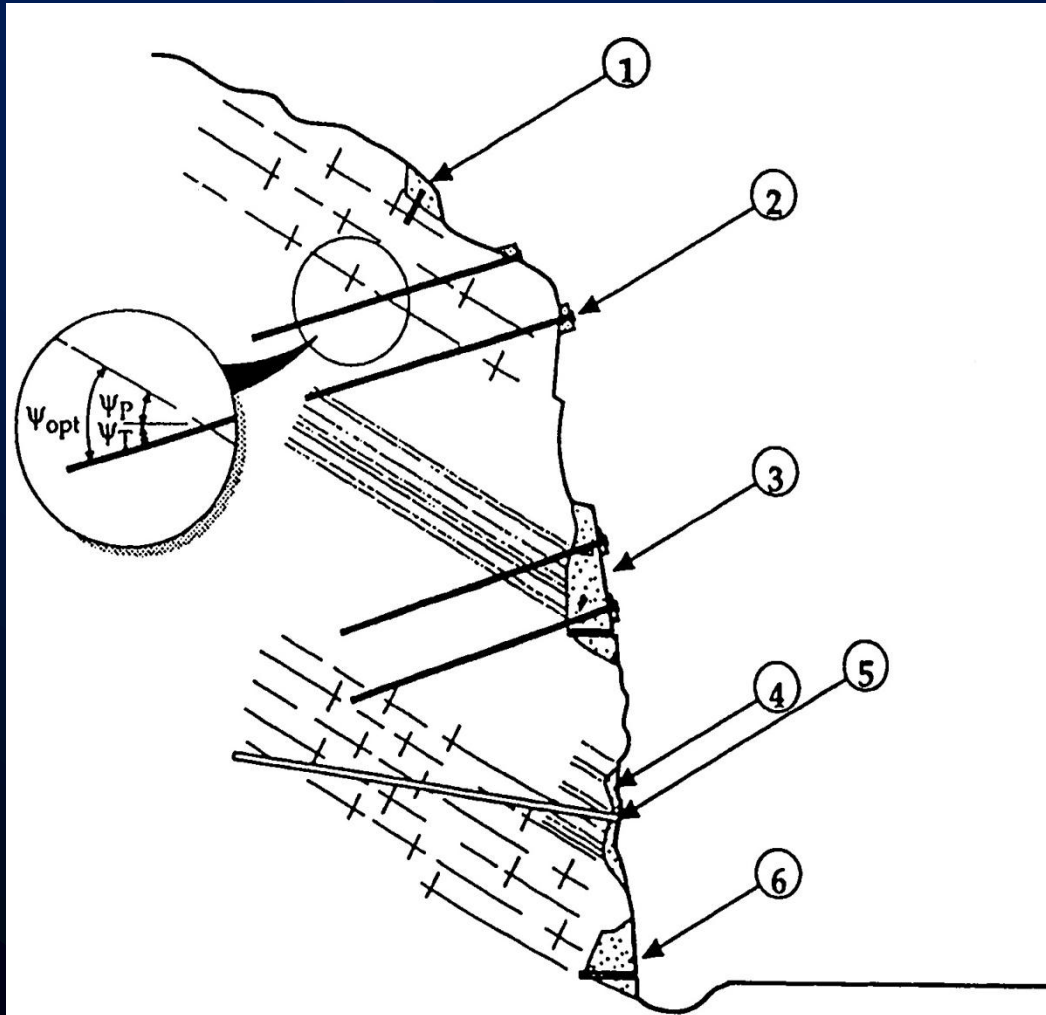
- ***List Rock Reinforcement Methods;***
- ***Identify Primary Components of Rock Bolting System;***
- ***Design Stabilization System for Planar Failure using Rock Bolts***
- ***Discuss shotcrete and drainage systems***

# ***Stabilization by Rock Reinforcement***

- ***Rock Bolts***
- ***Shear Keys***
- ***Tied-back Wall***
- ***Shotcrete***
- ***Buttress***
- ***Drainage***
- ***Shot-in-place Buttress***

***Figure 10-5***

# Stabilization by Rock Reinforcement



1. Reinforced concrete shear key to prevent loosening of slab at crest
2. Tensioned rock anchors to secure sliding failure along crest
3. Tieback wall to prevent sliding failure on fault zone
4. Shotcrete to prevent raveling of zone of fractured rock
5. Drain hole to reduce water pressure within slope
6. Concrete buttress to support rock above cavity



*Concrete shear keys*

# ***Rock Bolting – Design Procedure***

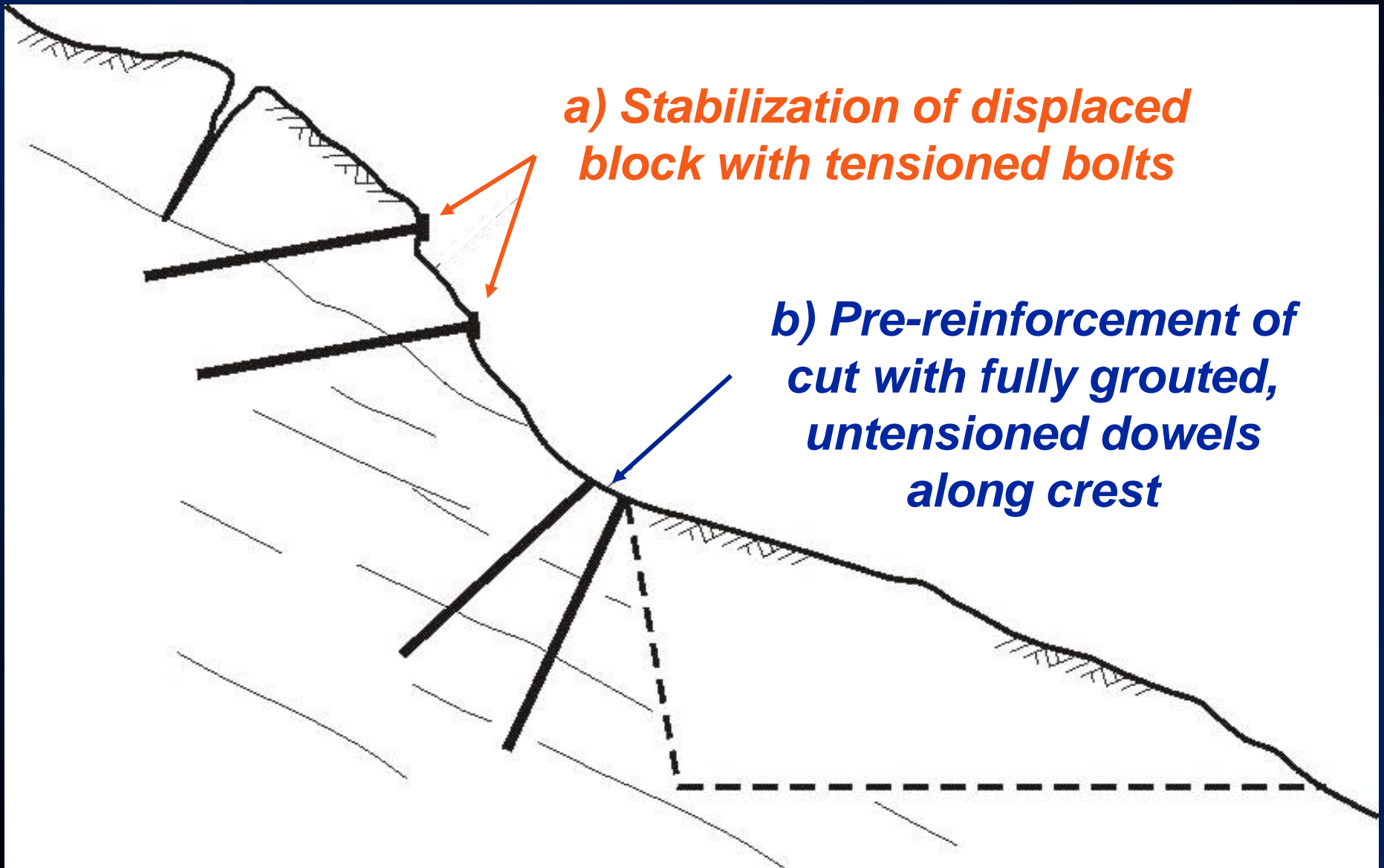
- ***Tensioned Bolts/Untensioned Dowels***
- ***Resin/ Cement / Mechanical Anchorage***
- ***Bond Length*** 
$$L_b = T / (\pi d_h \tau_a)$$

***Allowable Bond Stress ( $\tau_a$ ) - Table 10-3***

- ***Corrosion Protection***
- ***Tensioning - Load/Movement Measurements - PTI Acceptance Criteria***

***a) Stabilization of displaced block with tensioned bolts***

***b) Pre-reinforcement of cut with fully grouted, untensioned dowels along crest***





***Drill hole diameter compatible with drilling equipment – e.g. 5 in (125 mm) dia. hole***



***Crane access  
to face –  
costly,  
disruptive to  
traffic***



***Bencher drill and  
spider cage – low  
cost, 2-1/2 inch  
diameter hole,  
40 ft. depth.  
Little disruption to  
traffic***



***Reinforced  
concrete, tied-  
back grid in  
Japan***



**Reinforced concrete grid  
construction in Japan**

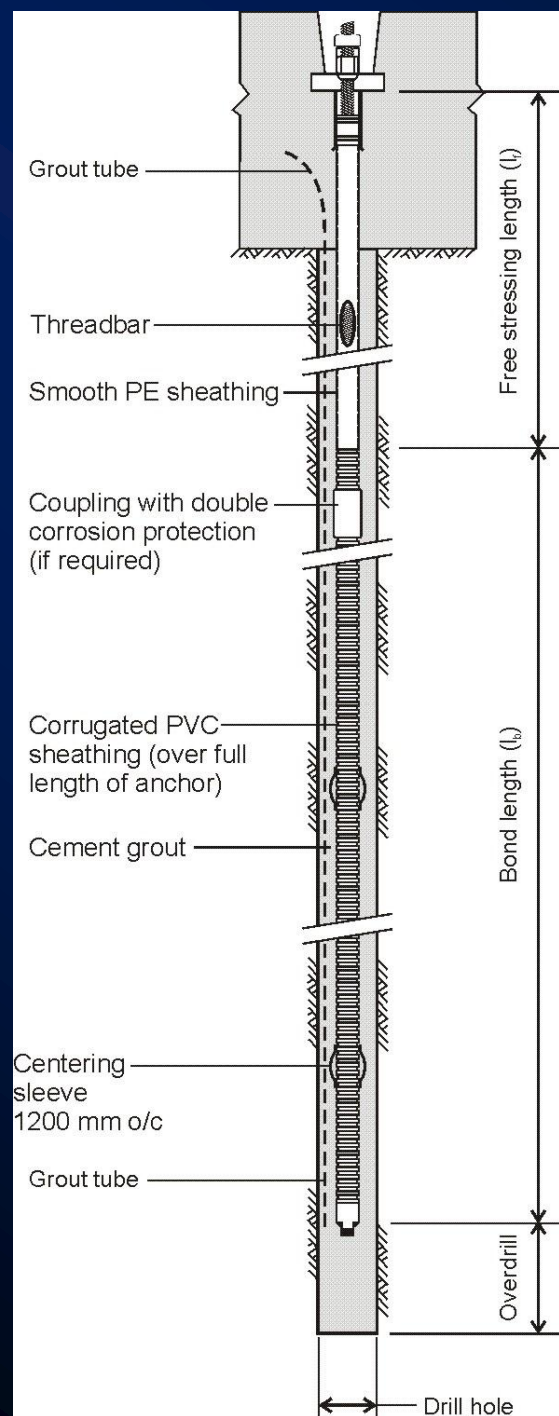
## ***Double corrosion bar anchors***

***Smooth sheath –  
stressing length***

***Corrugated sheath –  
bond zone***

***Centering sleeve***

***Grout tube***



## ***Double corrosion protected bar anchor***

# Ultimate vs Yield Strength Grade 150

$$0.85 \text{ in}^2 \times 150 \text{ ksi} = 127.5 \text{ kips} =$$

Ultimate

## R71 150 KSI All-Thread-Bar - ASTM A722

Bar Diameter	Minimum Net Area Thru Threads	Minimum Ultimate Strength	Minimum Yield Strength	Nominal Weight	Approx. Thread Major Dia.	Part Number
1" (26 mm)	0.85 in <sup>2</sup> (549 mm <sup>2</sup> )	127.5 kips (567.1 kN)	102 kips (453.6 kN)	3.09 lbs./ft. (4.6 Kg/M)	1-1/8" (28.6 mm)	R71-08
1-1/4" (32 mm)	1.25 in <sup>2</sup> (807 mm <sup>2</sup> )	187.5 kips (834 kN)	150 kips (667.2 kN)	4.51 lbs./ft. (6.71 Kg/M)	1-7/16" (36.5 mm)	R71-10
1-3/8" (36 mm)	1.58 in <sup>2</sup> (1019 mm <sup>2</sup> )	237 kips (1054.2 kN)	189.6 kips (843.4 kN)	5.71 lbs./ft. (8.50 Kg/M)	1-9/16" (39.7 mm)	R71-11
1-3/4" (45 mm)	2.60 in <sup>2</sup> (1664 mm <sup>2</sup> )	400 kips (1779.2 kN)	320 kips (1423.4 kN)	9.06 lbs./ft. (13.48 Kg/M)	2" (50.8 mm)	R71-14
2-1/2" (65 mm)	5.19 in <sup>2</sup> (3350 mm <sup>2</sup> )	778 kips (3457.0 kN)	622.4 kips (2765.8 kN)	18.20 lbs./ft. (27.1 Kg/M)	2-3/4" (69.9 mm)	R71-20

# Ultimate vs Yield Strength Grade 75

**0.44 in<sup>2</sup> x 75  
ksi**

**= 33 kips  
= Yield**

**R61 Grade 75 All-Thread Rebar - ASTM A615**

Bar Designation & Nominal Dia.	Minimum Net Area Thru Threads	Minimum Ultimate Strength	Minimum Yield Strength	Nominal Weight	Approx. Thread Major Dia.	Part Number
#6 - 3/4" (20 mm)	0.44 in <sup>2</sup> (284 mm <sup>2</sup> )	44 kips (195.7 kN)	33 kips (146.8 kN)	1.5 lbs./ft. (2.36 Kg/M)	7/8" (22.2 mm)	R61-06
#7 - 7/8" (22 mm)	0.60 in <sup>2</sup> (387 mm <sup>2</sup> )	60 kips (266.9 kN)	45 kips (200.2 kN)	2.0 lbs./ft. (3.04 Kg/M)	1" (25.4 mm)	R61-07
#8 - 1" (25 mm)	0.79 in <sup>2</sup> (510 mm <sup>2</sup> )	79 kips (351.4 kN)	59.3 kips (263.8 kN)	2.7 lbs./ft. (3.935 Kg/M)	1-1/8" (28.6 mm)	R61-08
#9 - 1-1/8" (28 mm)	1.00 in <sup>2</sup> (645 mm <sup>2</sup> )	100 kips (444.8 kN)	75 kips (333.6 kN)	3.4 lbs./ft. (5.06 Kg/M)	1-1/4" (31.8 mm)	R61-09
#10 - 1-1/4" (32 mm)	1.27 in <sup>2</sup> (819 mm <sup>2</sup> )	127 kips (564.9 kN)	95.3 kips (423.9 kN)	4.3 lbs./ft. (5.50 Kg/M)	1-3/8" (34.9 mm)	R61-10
#11 - 1-3/8" (35 mm)	1.56 in <sup>2</sup> (1006 mm <sup>2</sup> )	156 kips (694.0 kN)	117 kips (520.5 kN)	5.3 lbs./ft. (7.85 Kg/M)	1-1/2" (38.1 mm)	R61-11
#14 - 1-3/4" (45 mm)	2.25 in <sup>2</sup> (1452 mm <sup>2</sup> )	225 kips (1000.9 kN)	168.7 kips (750.4 kN)	7.65 lbs./ft. (11.78 Kg/M)	1-7/8" (47.6 mm)	R61-14
#18 - 2-1/4" (55 mm)	4.00 in <sup>2</sup> (2581 mm <sup>2</sup> )	400 kips (1779.4 kN)	300 kips (1334.5 kN)	13.6 lbs./ft. (19.63 Kg/M)	2-7/16" (61.9 mm)	R61-18
#20 - 2-1/2" (64 mm)	4.91 in <sup>2</sup> (3168 mm <sup>2</sup> )	491 kips (2184.0 kN)	368 kips (1637.0 kN)	16.69 lbs./ft. (24.84 Kg/M)	2-3/4" (69.9 mm)	R61-20
#28 - 3-1/2" (89 mm)	9.61 in <sup>2</sup> (6200 mm <sup>2</sup> )	960 kips (4274.0 kN)	720 kips (3206.0 kN)	32.7 lbs./ft. (48.60 Kg/M)	3-3/4" (95.0 mm)	R61-28

# **Typical Bar Stressing Limits:**

## **High Strength (Grade 150):**

*Maximum Design Load = 50 to 60% of guaranteed ultimate tensile strength (GUTS)*


*Maximum Test Load = 80% of guaranteed ultimate tensile strength (GUTS)*

## **Low Strength (Grade 60 or Grade 75):**

*Maximum Design Load = 60 to 70% of minimum yield strength*

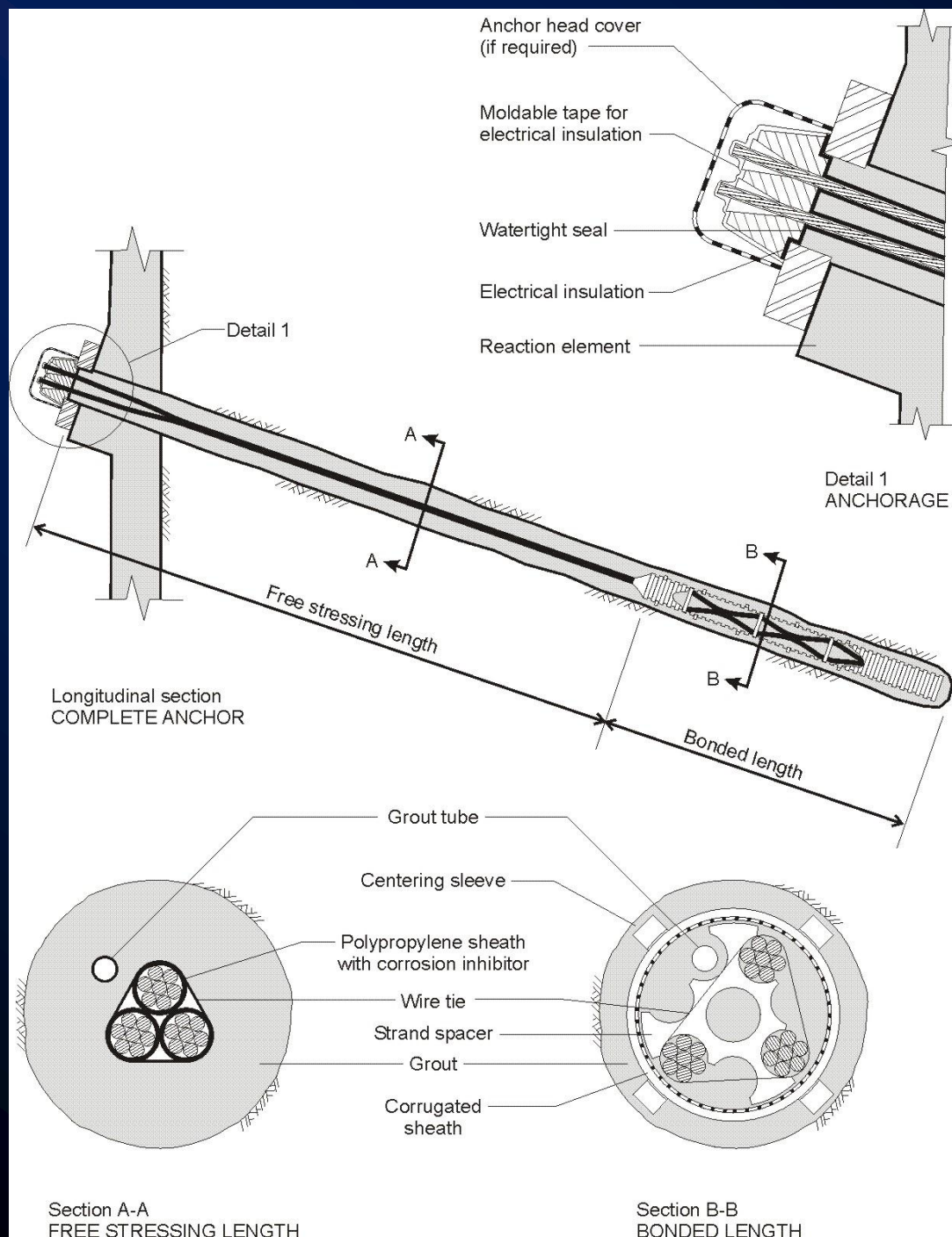
*Maximum Test Load = 90% of minimum yield strength*

**ALWAYS VERIFY WITH MANUFACTURER**



*Five-strand  
cable anchor*

*Wedge  
cable  
gripper*



## ***Double corrosion protected 3-strand cable anchor***



***Cement grout  
mixer and  
pump***



***Resin  
anchor  
cartridges***



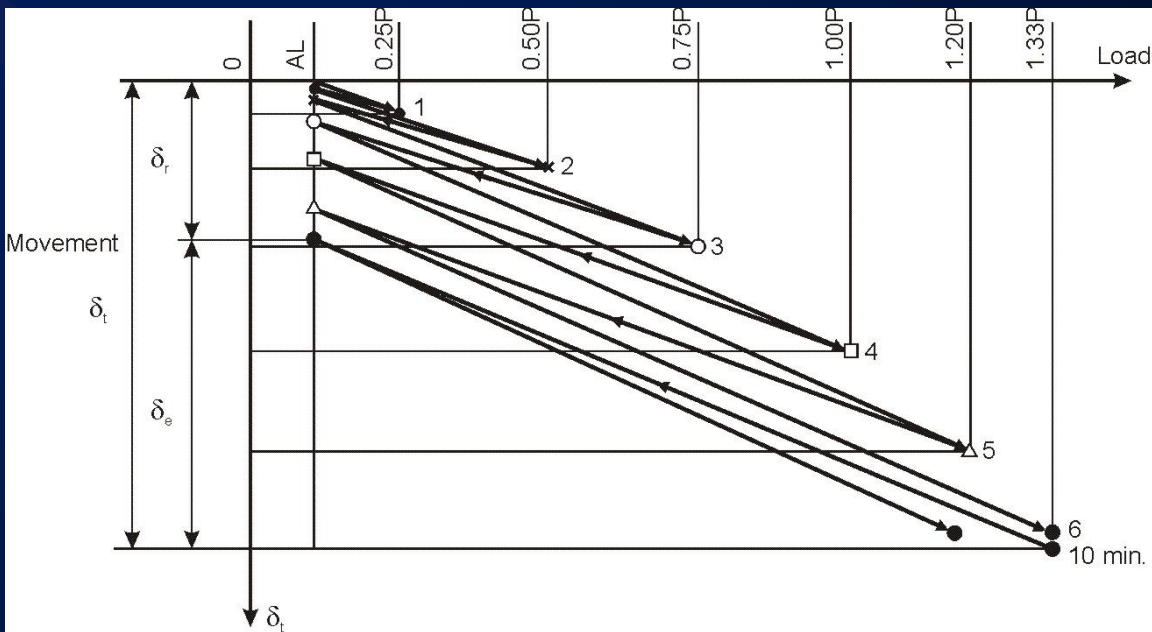
*Anchor supported on lifting cradle*



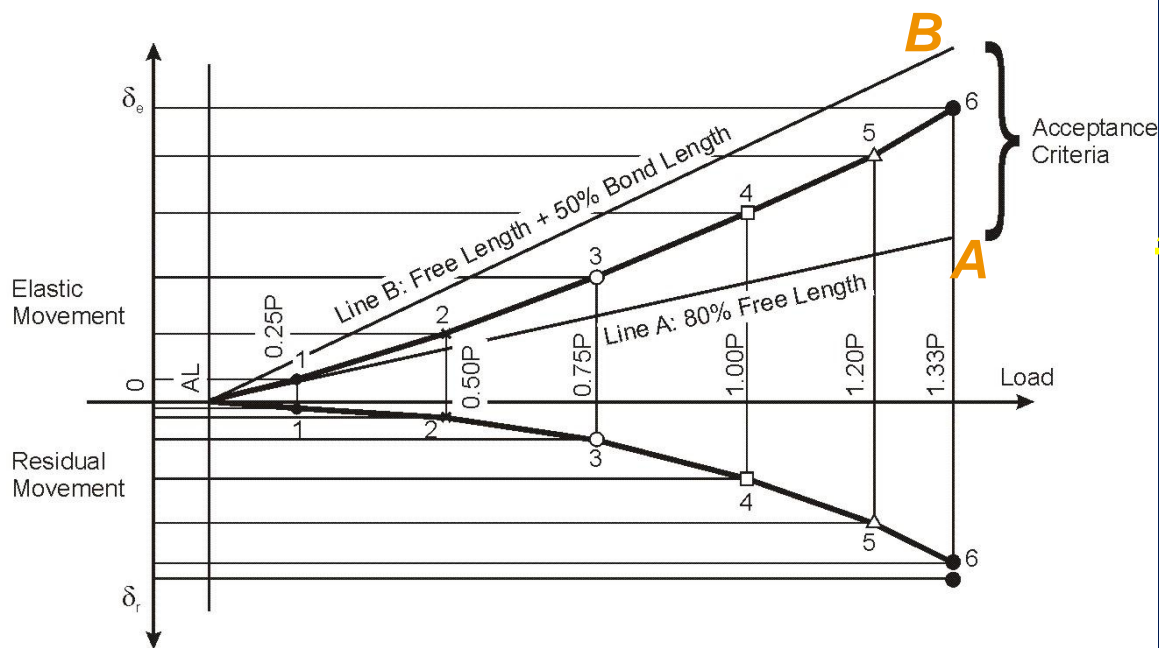
***Rock bolts with shotcrete facing  
to contain closely jointed rock***

***Tensioning multi-strand with  
hydraulic jack; dial gauge to  
measure elongation***

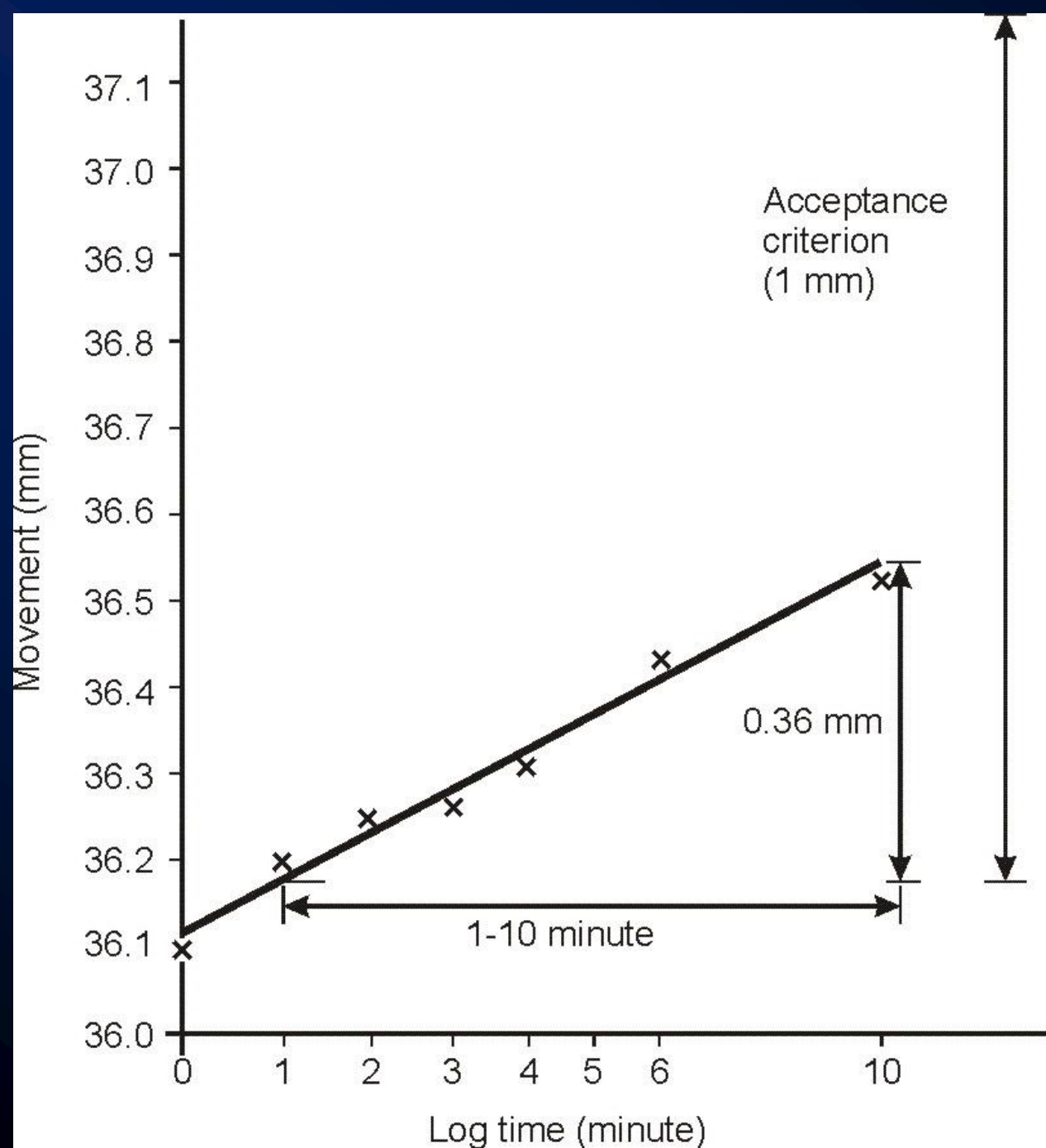




**Performance test –  
cyclic loading with  
elongation  
measurements**



**Acceptance criteria –  
Line A and Line B  
allowable  
movements**



**Creep test –  
semi-log plot of  
time versus  
elongation**

# ***Student Exercise – planar slope reinforcement using rock bolts.***

***Student Exercises No. 4 and No. 7  
Page 4-1, 4-8***

# ***Stabilization by Rock Reinforcement***

- ***Shotcrete***



***Dry mix shotcreting  
operation – water  
added at nozzle***



***Unreinforced shotcrete on  
weathered rock – rapid spalling***

*Pre-moisturizer*



8-23-93

*Dry-mix shotcrete supplied in  
1 cu. yd. bags*



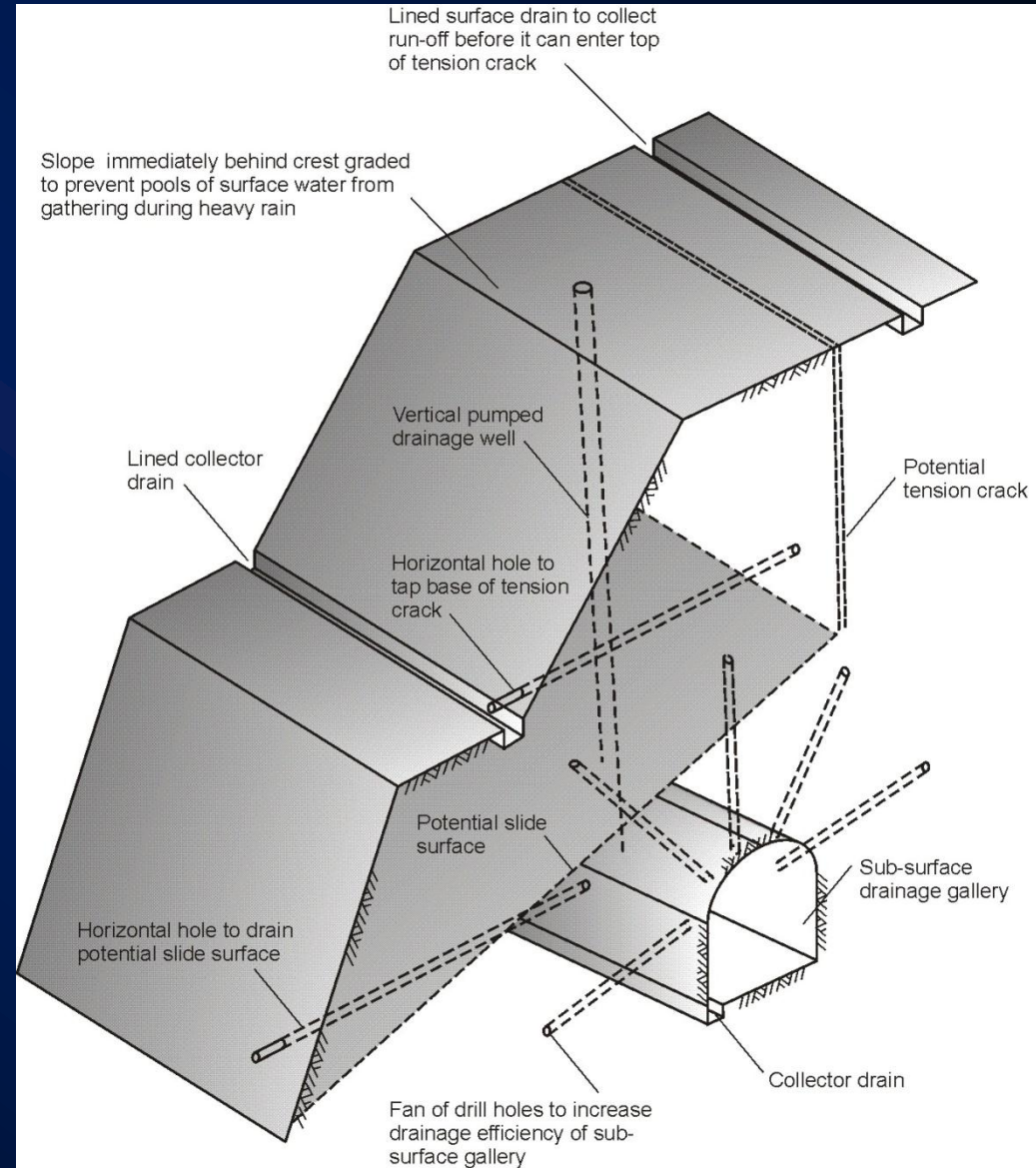
***Shotcrete  
application from  
man-lift with rigid  
boom***



***Sculpted and colored shotcrete***

# Stabilization by Rock Reinforcement

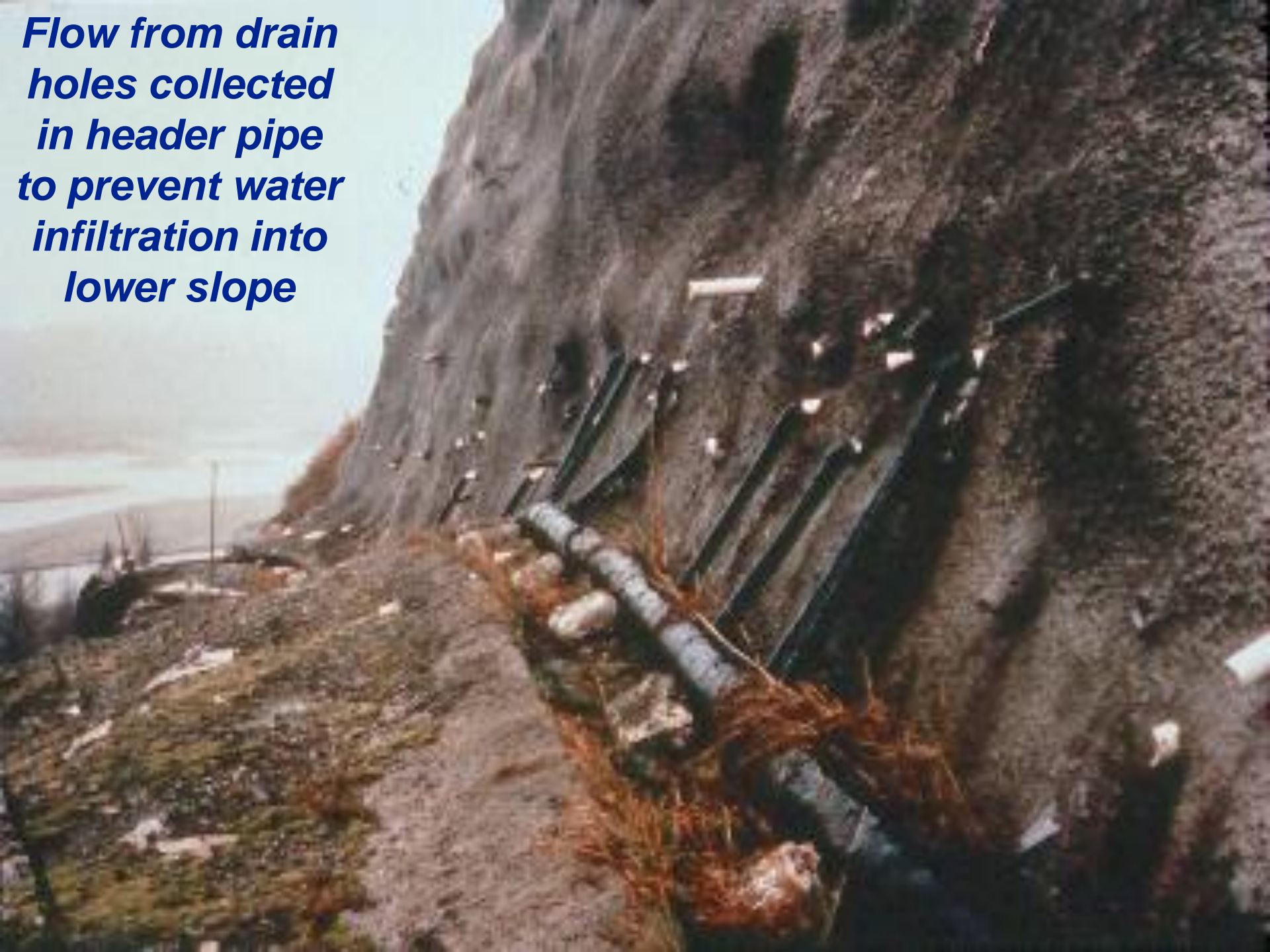
## ■ Drainage





***Drain holes  
must intersect  
discontinuities  
carrying water***

***Flow from drain  
holes collected  
in header pipe  
to prevent water  
infiltration into  
lower slope***



# ***LESSON 8B – ROCK REINFORCEMENT METHODS***

## ***Learning Outcomes -***

- ***List Common Rock Reinforcement Methods;***
- ***Identify Primary Components of Rock Bolting System;***
- ***Design Stabilization System for Planar Failure using Rock Bolts;***
- ***Discuss shotcrete and drainage systems***



